Appendix A Summary of Large Storm Hydrology

The computational procedures for large storm hydrology consist of techniques for estimating or modeling runoff hydrographs from larger storm events typically ranging from the 1-yr to the 100-yr storm. The procedures for conducting these analyses are well documented at both the national and regional levels.

Federally Funded Models

At the national level, a variety of models that simulate rainfall-runoff processes for watersheds and the design of BMPs are available and well documented. Selection of the appropriate modeling technique will often depend on the level of detail and rigor required for the application and amount of data available for setup and testing of the model results. However, in many instances local regulatory agencies may specify which models are acceptable for design and review purposes. For example, in the state of Maryland, the state regulatory authority, the Maryland Department of the Environment, requires that BMP design be performed using the NRCS TR-55 and TR-20 models.

Detailed guidance on the use of these models is beyond the scope of this manual. A brief overview of the following national models is provided here:

- HEC-1/HEC-HMS Flood Hydrograph Package
- HSPF - Hydrologic Simulation Program - FORTRAN
- SWMM - Storm Water Management Model
- TR-55/TR-20
- WMS - Watershed Modeling System

HEC-1/HEC-HMS Flood Hydrograph Package

HEC-1 was developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers to simulate the surface runoff response of a watershed to rainfall events. Although it is a DOS-based program, it is still considered by many in the engineering and regulatory communities to be the leading model for major drainage system applications such as Flood Insurance Studies and watershed master planning. HEC-1 is accepted by the Federal Emergency Management Agency and therefore is the most widely used model for major drainage system analyses.

In HEC-1, the watershed is represented in the model as an interconnected system of hydrologic (i.e., subbasins, reservoirs, ponds) and hydraulic (i.e., channels, closed conduits, pumps) components. The model computes a runoff hydrograph at each component, combining two or more hydrographs as it moves downstream in the watershed. The model has a variety of rainfall-runoff simulation methods, including the popular NRCS Curve Number methodology. The user can define rainfall events using gage or historical data, or HEC-1 can generate synthetic storms. Hydrograph generation is performed using the unit hydrograph technique. Clark, SCS Dimensionless and Snyder Unit Hydrographs are the available methodologies. Several common channel and storage routing techniques are available as well. HEC-1 is not considered a "design tool." The program has limited hydraulic capabilities. It does not account for tailwater effects and cannot adequately simulate many urban hydraulic structures such as pipe networks, culverts and multi-stage detention pond outlet structures. However, there are other hydrologic applications developed within HEC-1 that have been utilized with much success. Multiplan-multiflood analyses allow the user to simulate a number of flood events for different watershed situations (or plans). The dam safety option enables the user to analyze the impact dam overtopping or structural failure on downstream areas. Flood damage analyses assess the economic impact of flood damage.

Because it is not a Windows-based program, HEC-1 does not have easy to use input and output report generation and graphical capabilities, and therefore is generally not considered a user-friendly program. Because of its wide acceptance, however, several software development companies have incorporated the source code into enhanced "shells" to provide a user-friendly interface and graphical input and output capabilities. Examples of these programs include Graphical HEC-1, developed by Haested Methods and WMS, developed by the Environmental Modeling Research Laboratory.

The Corps of Engineers has developed a user-friendly, Windows-based Hydrologic Modeling System (HEC-HMS) intended to replace the DOS-based HEC-1 model. The new program has all the components of HEC-1, with more user-friendly input and output processors and graphical capabilities. HEC-1 files can be imported into HEC-HMS. Version 2 of this model has been released. Information regarding these two programs cab be obtained from the U.S Army Corps of Engineers at the following address:

Corps of Engineers
Hydrologic Engineering Center
609 Second Avenue
Davis, California 95616
Tel: 530-756-1104
Website: http://www.hec.usace.army.mil/

Hydrologic Simulation Program - FORTRAN (HSPF).

The HSPF model was developed by the EPA for the continuous or single-event simulation of runoff quantity and quality from a watershed. The original model was developed from the Stanford Watershed Model, which simulated runoff quantity only. It was expanded to include quality components and has since become a popular model for continuous non-point source water quality simulations. Non-point source conventional and toxic organic pollutants from urban and agricultural land uses can be simulated, on pervious and impervious land surfaces and in streams and well-mixed impoundments. The various hydrologic processes are represented mathematically as flows and storages. The watershed is divided into land segments, channel reaches and reservoirs. Water, sediment and pollutants leaving a land segment move laterally to a downstream land segment, a stream or river reach or reservoir. Infiltration is considered for pervious land segments.

HSPF model output includes time series information for water quality and quantity, flow rates, sediment loads, and nutrient and pesticide concentrations. To manage the large amounts of data associated with the model, HSPF includes a database management system. To date, HSPF is still a DOS-based model and therefore does not have the useful graphical and editing options of a Windows-based program. Input data requirements for the model are extensive and the model takes some time to learn. However the EPA continues to expand and develop HSPF, and still recommends it for the continuous simulation of hydrology and water quality in watersheds.

At this time, this model can be used to develop runoff hydrographs and water quality loadings from watersheds, but currently cannot be used for BMP design.

The U.S. Geological Survey has become the point of contact for the operation, maintenance and distribution of this model. Information can be obtained at the following location:

U.S. Geological Survey
Hydrological Analysis Software Support Program
437 National Center
Reston, VA 20192
email: h2osoft@usgs.gov
website: http://water.usgs.gov/software/

EPA SWMM - Storm Water Management Model

EPA SWMM (Huber and Dickinson, 1988) was developed by the EPA to analyze storm water quantity and quality problems associated with runoff from urban areas. EPA SWMM has become the model of choice for simulation of minor drainage systems primarily composed of closed conduits. The model can simulate both single-event and continuous events, and has the capability to model both wet and dry weather flow. The basic output from SWMM consists of runoff hydrographs, pollutographs, storage volumes and flow stages and depths.

SWMM's hydraulic computations are link-node based and are performed in separate modules, called blocks. The EXTRAN computational block solves complete dynamic flow routing equations to simulate backwater, looped pipe connections, manhole surcharging and pressure flow. It is the most comprehensive model in its capabilities to simulate urban storm flow and many cities have used it successfully for storm water, sanitary or combined sewer system modeling. Open channel flow can be simulated using the TRANSPORT block, which solves the kinematic wave equations for natural channel cross-sections.

SWMM has both hydrologic and water quality components. Hydrologic processes are simulated using the RUNOFF block, which computes the quantity and quality of runoff from drainage areas and routes the flow to major sewer system lines. Pollutant transport is simulated in tandem with hydrologic and hydraulic computations, and consists of calculation of pollutant buildup and washoff from land surfaces, and pollutant routing, scour and in-conduit suspension in flow conduits and channels.

EPA SWMM is a public domain model; version IV is currently available and a newer version V is to be released. For large watersheds with extensive pipe networks, input and output processing can be tedious and confusing. Because of the popularity of the model, commercial, third-party enhancements to SWMM have become more common, making the model a strong choice for minor system drainage modeling. Examples of commercially enhanced versions of EPA SWMM include MIKE SWMM, distributed by BOSS International, XPSWMM by XP-Software, and PCSWMM by Computational Hydraulics Inc. (CHI). CHI also developed PCSWMM GIS, which ties the SWMM model to a GIS platform.

General Description of SWMM

The original SWMM program consisted of the following six blocks (see Figure A-1); runoff, transport, extended transport (EXTRAN), storage/treatment, receiving water and executive.

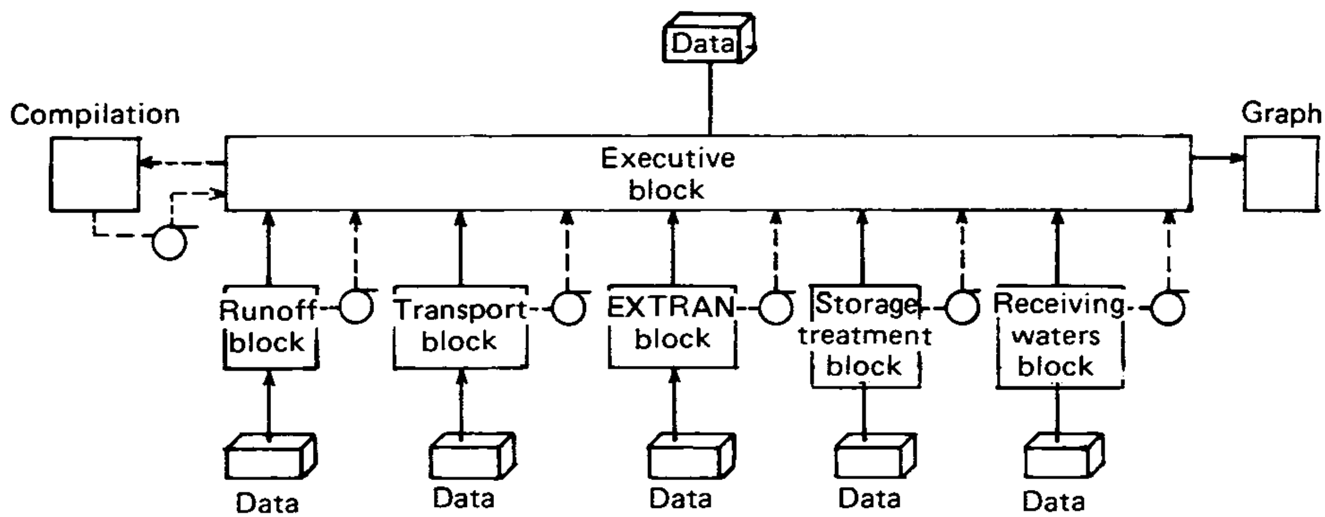

Figure A-1 SWMM Program Blocks

These blocks are not used simultaneously. Only the blocks best suited for a specific task are used at any given time. Output from one block can be used as input for another. This provides SWMM great flexibility and a staged approach to modeling complex systems.

Runoff Block. The Runoff Block is used to estimate stormwater runoff from various subwatersheds and its output can be used as input to the transport, EXTRAN, storage/treatment or receiving blocks. Initial storm runoff calculations are based on sheet flow kinematic wave principle for the water that is not lost due to infiltration and surface retention. Any temporal and spatial distribution of rainfall can be used as input. Sheet flow, including the simulated pollutant load, is intercepted by trapezoidal gutters and circular pipes, which are then combined with flow and pollutants in other gutters and pipes. All flows and pollutants are eventually routed to specified discharge points. It is not necessary, however, to simulate pollutant runoff in order to use the runoff block.

Transport Block. The Transport Block simulates the flow and pollutant transport in the major sewers of the system. Input data for the Transport Block consists of the output from the Runoff Block. This block can also simulate detention facilities at any point in the system. The calculations are based on the normal depth and continuity principle, which means they do not account for backwater effects or surcharge. If the inflow into any sewer segment exceeds its pipe full capacity, the excess is temporarily stored at the upstream end of the pipe segment. This algorithm has a tendency to underestimate needed detention volumes.

Extended Transport Block (EXTRAN). By replacing the Transport Block by EXTRAN, it is possible to account for backwater effects in the flow conveyance system. The pressure gradient can go up to the ground surface at the nodes of the model. When the incoming flows surcharge the system so that it reaches the surface, the excess flows are not returned to the system. As a result, continuity is not maintained when a sewer system is surcharged excessively. EXTRAN also provides for the simulation of certain standard facilities such as overflows, pumping stations, detention facilities, etc.

Storage/Treatment Block. This block allows for simplified simulation of a single treatment plant in the system. The plant, however, has to be located at the downstream end of the sewer network. The treatment plant can include a single detention storage basin.

Receiving Water Block. The Receiving Water Block was originally designed to simulate the hydraulics and the fate of pollutants in the receiving bodies of water such as rivers, lakes, estuaries, etc. This block was not updated with later versions of SWMM and is typically no longer used due to the availability of other receiving water models. The loadings generated from SWMM can be imported to other receiving water models, e.g. WASP.

Executive Block. This block has the task of coordinating the information and transferring data between all of the other blocks in SWMM.

Detention Calculations in Transport Block

The Transport Block in SWMM can be used to approximate in-line and off-line detention storage in the sewer system. At most, two storage basins can be simulated by this block (see Figure A-2). If there are more than two basins, the system has to be broken up into smaller subsystems that can be simulated sequentially using the results of the upper network as input into the lower sewer network. The input data needed for storage calculations will include the following:

- Type of outlet structure. The choices provided by the model include bottom orifice outlet, constant rate pump and a spillway.
- Depth-area relationship for up to 11 different water levels. This may be simplified in the case of a storage basin having the shape of an inverted circular truncated cone, in which case the user inputs only the bottom area and the slope of the walls.
- The maximum water level.
- The water level and the discharge rate at the start of the simulation.

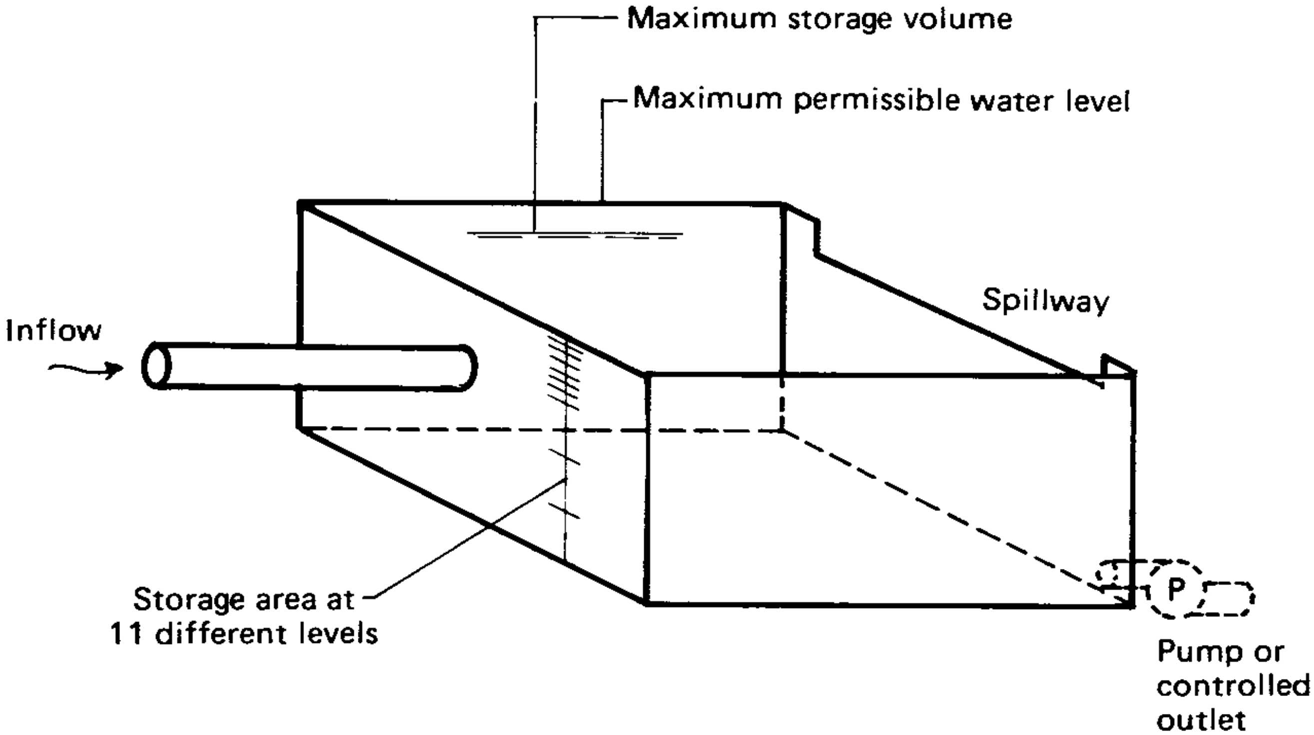

Figure A-2 Detention facility as defined in Transport Block

The following three equations are used to describe the discharge through each type of outlet:

Bottom Orifice Outlet: $Q = A \times K_1 \times H^{1/2}$ (A-1)

Spillway: $Q = L \times K_2 \times (H - h)^{3/2}$ (A-2)

Constant Rate Pump: $Q = K_3$ (A-3)

Where:

- Q = discharge rate,
- H = depth of water above basin bottom,
- A = area of the orifice outlet,
- K_l = constant dependent on orifice configuration,
- L = length of spillway,
- K_2 = constant dependent on spillway configuration,
- h = height of spillway crest above basin bottom, and
- K_3 = constant pump capacity.

When the pump option is used, it is also necessary to input the levels at which the pump is turned on and off. If the water level in the storage basin during simulation rises above the maximum permissible level, the excess is not routed through the storage basin. Instead, it is accounted as excess volume in the printout of the simulation. This way, the modeler is aware of how much the basin may have been overloaded.

The pollutants in the system can also be routed through the storage basin. The program can estimate the removal of the settleable pollutants within the storage basin. This simulation can be performed at the user's discretion using plug flow or total mixed flow assumptions. As a result, the program provides the modeler with a simulated hydrograph and a pollutograph after they are routed through the detention basin. Also, for each time step, the output provides the water depth and storage volume. The program does not provide a hydrograph of the water that may exceed the storage capacity of the facility and may spill as uncontrolled overflow.

Detention Calculations in Storage/Treatment Block

The SWMM program permits simulation of a treatment plant located at the downstream end of the system. Simulation of the following treatment plant components and processes is possible: gratings, swirl concentrator, sand trap, flotation, strainer, sedimentation, filtration, biological treatment and chlorination.

The modeler excludes those treatment steps that are not applicable and provides the necessary basic parameters for the processes to be used. A storage facility can be located in-line or off-line to the sewer pipe entering the plant (see Figure A-3). It is possible to use connection schemes of detention and treatment plant other than those shown in this figure. For example, when the storage is connected off-line, it is possible to route or pump the water from the storage basin to the plant.

Simulation of detention in this block is done using the same mathematic equations as used in the transport block described earlier. The only difference is that in the Storage/Treatment Block, the user has to specify the treatment efficiency for pollutant removal in the detention storage facility.

Detention Calculations in the EXTRAN Block

In the EXTRAN Block, the sewer network is represented by a series of links that are connected to each other at nodes. The modeler provides geometry, roughness and invert elevations for each pipe. The user also has to provide the ground surface elevation at each node (i.e., manhole). Detention is simulated simply by providing the geometry of a pipe that best describes the storage vs. volume relationship of the installation. If the storage facility has an unusual shape, its characteristics can be approximated using any combination of pipes connected in parallel and series. The pipe sections supplied by the program are illustrated in Figure A-4. The user may, however, describe additional pipes having any desired geometry.

It is possible to simplify the initial testing of a potential detention storage site without going into great geometric detail of the facility. This is done by defining node storage basins. All that is needed is to input the water surface area available at the node in question. EXTRAN assumes that the surface area remains constant as the water rises and falls and calculates the volume being stored at the node.

The outflow from a storage basin in EXTRAN is described by either giving the dimensions of the outlet pipe or one of the following flow regulating elements: overflows, outlet orifices, pumps and high-water gates.

When these regulation elements are used to describe the discharge characteristics between two nodes, the user has to enter their hydraulic characteristics, i.e., discharge coefficients, spillway lengths, pumping rates, etc. An example of how a detention basin can be simulated using links, nodes and flow regulating elements is illustrated in Figure A-5.

The output from the EXTRAN block can provide for each time step the flow velocities in all the pipes and water levels at all the nodes in the sewer network. At each of the detention sites, the inflow hydrograph, the outflow hydrograph and the water levels are interdependent, and are calculated simultaneously for each time step. This block is not simple to use, since all the component parts of the sewer system have to be described in detail and the calculations tend to become unstable if the element lengths are too short. It is a powerful tool for analysis of an existing system and for testing proposed designs. It is not, however, the block that one would use for the general screening of many alternatives during planning.

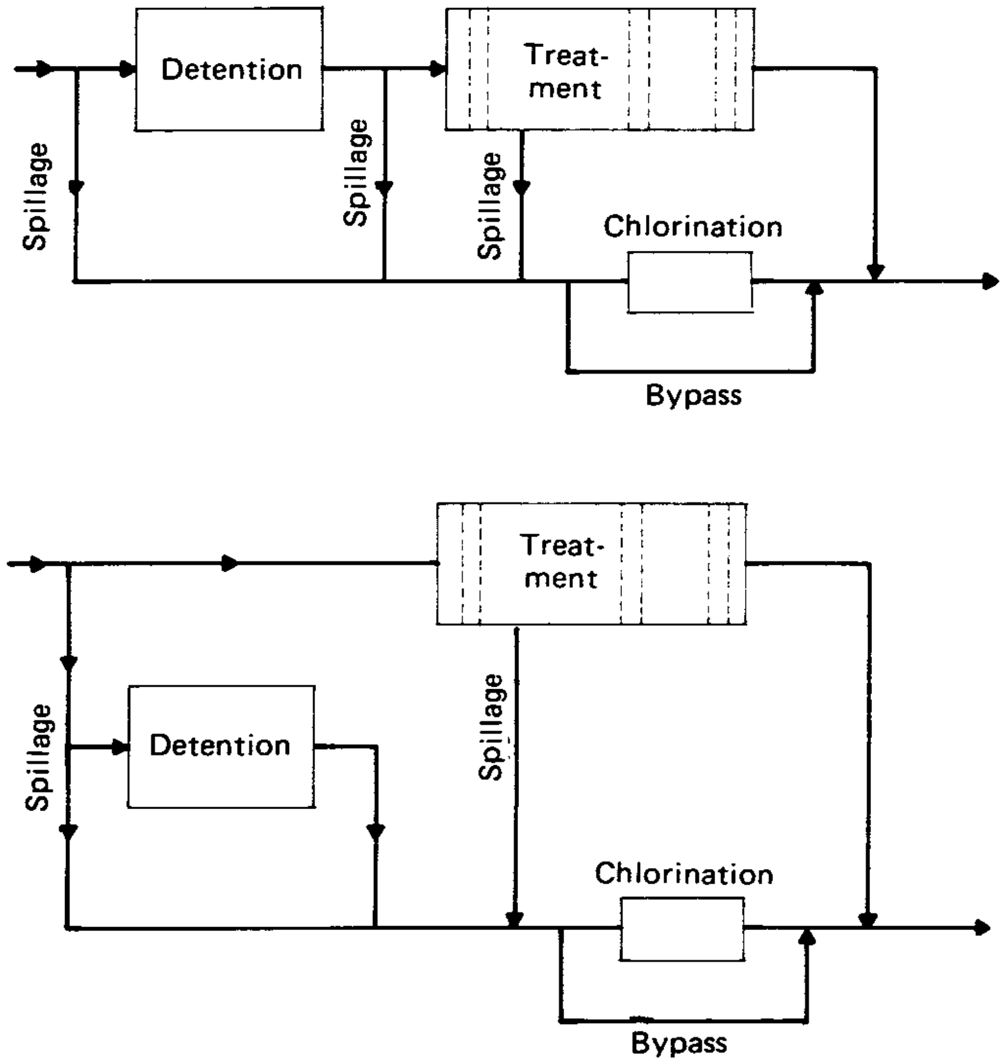

Figure A-3 Treatment processes simulated by Storage Treatment Block of SWMM

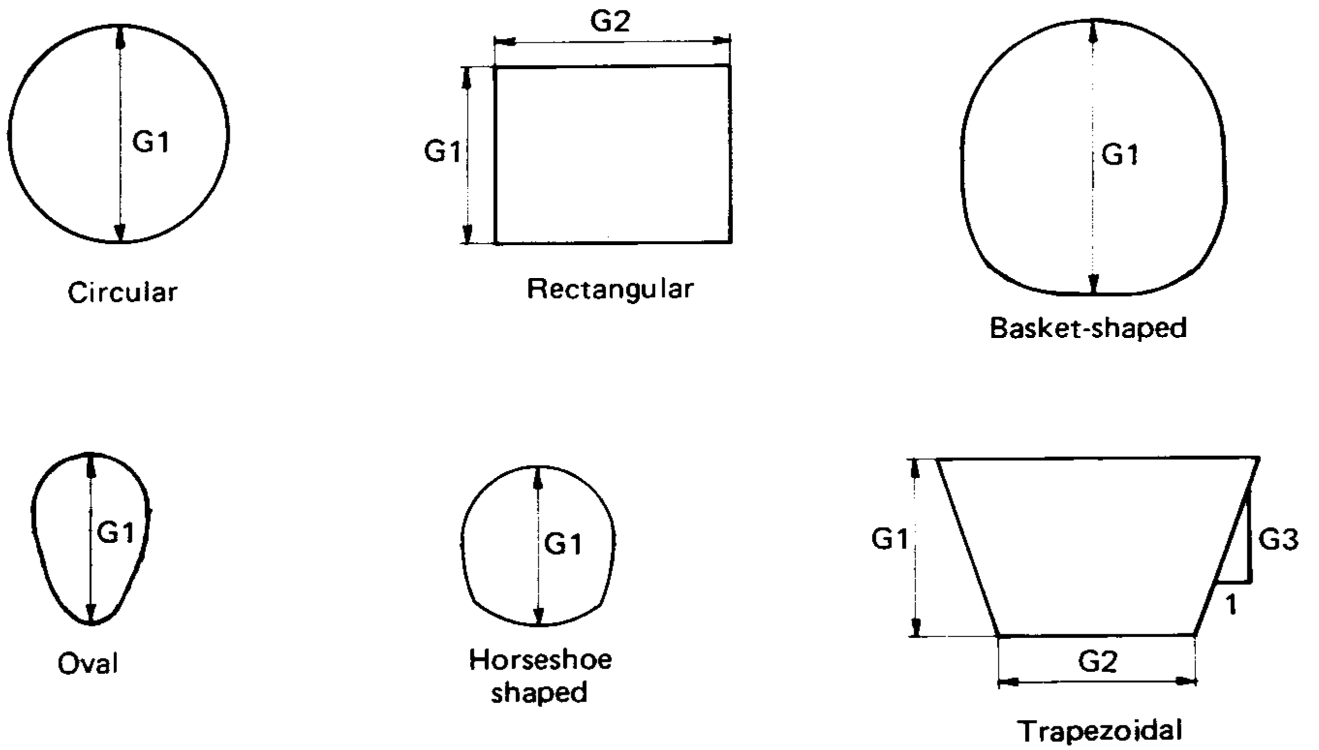

Figure A-4 Standard pipe sections provided in EXTRAN Block.

Summary of SWMM Model Description

Detention calculations can be performed by the SWMM program in the following blocks: Transport Block, Extended Transport Block (EXTRAN) and Storage/Treatment Block.

The same mathematical equations are used in detention calculations in the Transport Block and the Storage/Treatment Block. The latter block only permits the simulation of detention at a treatment facility. Backwater effects are not considered in the Transport Block. If backwater effects are of significant concern, the Transport Block can be replaced by EXTRAN, which accounts for water surface levels in the entire system.

Using SWMM, one can simulate most of the urban storm runoff and routing processes. SWMM is a comprehensive and powerful model and can be an extremely valuable tool in experienced hands. However, the model is complicated and imposes many requirements on the user. It is not a model of choice for casual investigation of what detention requirements may be needed at a single site. It is the model of choice for analyzing the performance of complete storm sewer systems, which may include detention facilities within such systems.

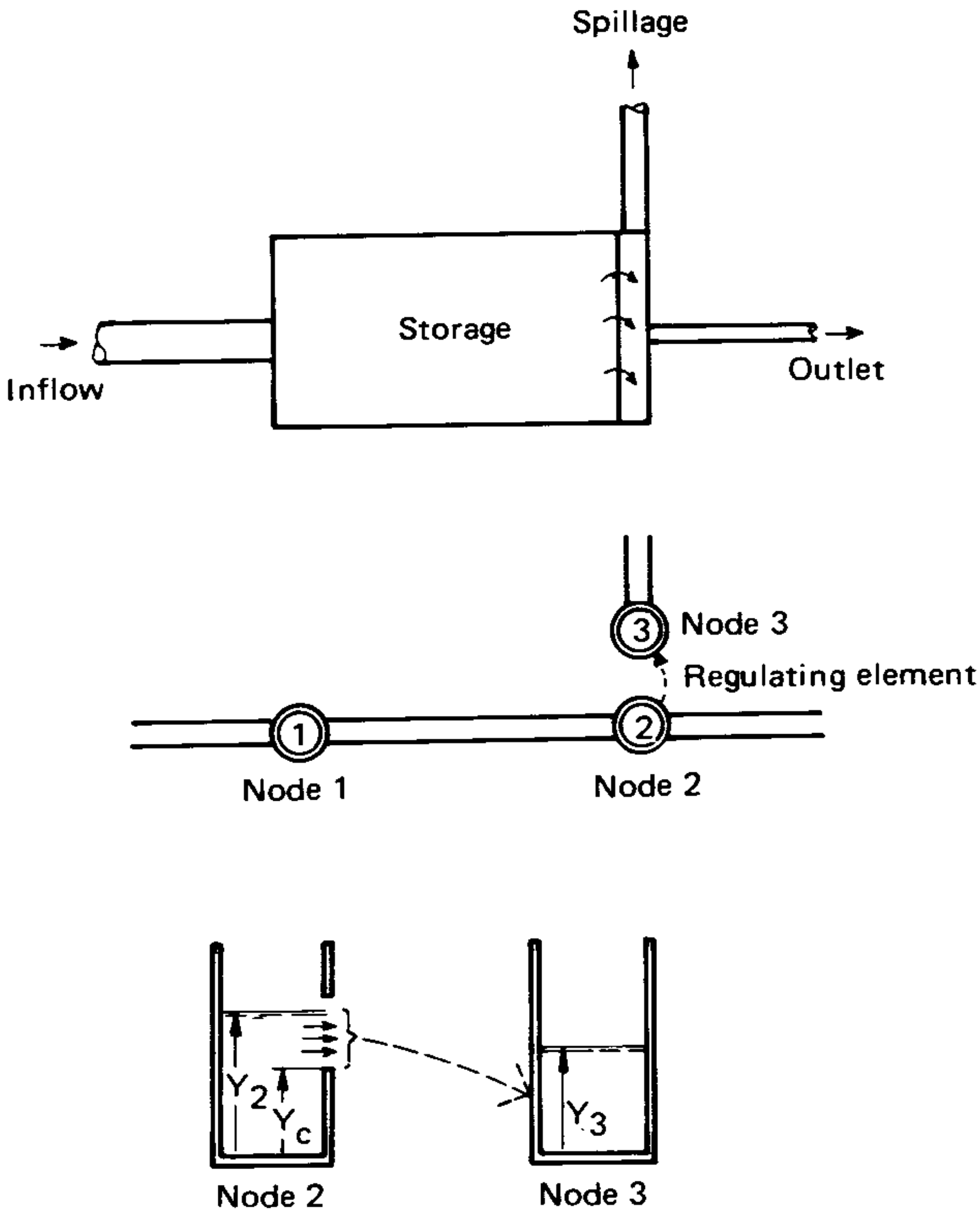

Figure A-5 Example of how detention can be described using links, nodes and flow regulators in EXTRAN Block

TR-55/TR-20

TR-55 - Technical Release 55

The TR-55 model is a DOS-based software package used for estimating runoff hydrographs and peak discharges for small urban watersheds. The model was developed by the NRCS (formally SCS) and therefore uses SCS hydrograph methodology to estimate runoff. No other methodology is available in the program. Four 24-hr regional rainfall distributions are available for use. Rainfall durations less than 24-hr cannot be simulated. Using detailed input data entered by the user, the TR-55 model can calculate the area-weighted CN, time of concentration and travel time. Detention pond (i.e., storage) analysis is also available in the TR-55 model and is intended for initial pond sizing. Final design requires a more detailed analysis.

TR-55 is easy-to-use, however because it is DOS-based it does not have the useful editing and graphical capabilities of a Windows-based program. Haestad Methods, Inc., included most of the TR-55 capabilities in its PondPack, which is available commercially.

TR-20 Watershed Hydrology Model

TR-20 (Technical Release Number 20, Computer program for Project Formulation - Hydrology) had existed for 16 years in draft status . In the fall of 1997, the newly formed TR-20 work group made the momentous decision to revise, modernize and finalize the program. The TR-20 Watershed Hydrology model is a rewritten and expanded version of the older TR-20.

TR-20 Watershed Hydrology Model is a USDA Natural Resources Conservation Service system of computer models developed to predict the runoff resulting from rainfall over a watershed. The model is also part of the TR-20 User System, an umbrella that includes pre- and post processing functions in addition to the actual model. The TR-20 model is written in ANSI standard Fortran 90 and developed in a WindowsNT programming environment using the DEC Visual Fortran 6.0 compiler. This programming effort also includes changing the philosophy of data input, developing a Windows input interface and output post-processor and adding GIS capability to the program. A converter program will reformat old input data sets so they can be run in the new program version.

The system of TR-20 computer programs consist of: (1) input generation and editing, (2) GIS based data generator, (3) old data set converter, (4) TR-20 HEC-RAS rating, (5) main program, (6) output files and (7) post processing programs.

The system of TR-20 and TR-55 computer programs is available from the National Water and Climate Center website (http://www.wcc.nrcs.usda.gov).

WMS - Watershed Modeling System

WMS was developed by the Engineer Computer Graphics Laboratory of Brigham Young University.

WMS is a Windows-based user interface that provides a link between terrain models and GIS software, with industry standard lumped parameter hydrologic models, including HEC-1, TR-55, TR-20 and others. The hydrologic models can be run from the WMS interface. The link between the spatial terrain data and the hydrologic model(s) gives the user the ability to develop hydrologic data that is typically gathered using manual methods from within the program. For example, when using NRCS methodologies, the user can delineate watersheds and subbasins, determine areas and curve numbers, and calculate the time of concentration at the computer. Typically, these computations are done manually, and are laborious and time-consuming. WMS attempts to utilize digital spatial data to make these tasks more efficient.

Watershed Modeling

The Watershed Modeling program was developed to compute runoff and design flood control. The program can run inside the MicroStation CAD system. Like WMS, this feature enables the program to delineate and analyze the drainage area of interest. Area, curve number, land use and other hydrologic parameters can be computed and/or catalogued for the user, removing much of the manual calculation typically performed by the hydrologic modeler.

Watershed Modeling contains a variety of methods to calculate flood hydrographs, including NRCS, Snyder and Rational methods. Rainfall can be synthetic or user-defined, with any duration and return period. Rainfall maps for the entire U.S. are provided to help the user calculate IDF relationships. Several techniques are available for channel and storage routing. The user also has a wide variety of outlet structure options for detention pond analysis and design.

Regional Models

A number of large storm models have also been developed by local and regional government. Some of these models include:

- PSRM - The Penn State Runoff Model (Aron et al., 1992), which is used widely in Pennsylvania and Virginia
- ILLUDAS - The Illinois Urban Area Simulator, which was developed by the Illinois State Water Survey and is widely used in Illinois and neighboring mid-western states.
- UDFCD - The Urban Drainage and Flood Control District model, developed by the Denver Urban Drainage Flood Control District (UDFCD, 1999). This model is used widely in Colorado and adjoining states.
- The Santa Barbara Urban Runoff Hydrograph, developed for the City of Santa Barbara California. This model is widely used in California and other pacific coast states (Oregon and Washington).

A brief description of these large storm regional hydrologic models is provided below.

PSRM - The Penn State Runoff Model

The Penn State Runoff Model (PSRM) and PSRM-QUAL are the most recent modifications of the Penn State Runoff Model (Aron et al., 1992) and is available from the Pennsylvania State University Department of Civil and Environmental Engineering (telephone: 814-865-8391). This model incorporates both runoff quantity and water quality routines, and is widely used in Pennsylvania and Virginia for the design of SWM BMPs.

Components of the quantity model include overland runoff, stream/pipe flow, surcharging, routing through channels and reservoirs, and multiple storm considerations. The quality modeling routine includes methods for determining contaminants in urban runoff and their effects.

The quantity algorithm simulates the runoff and pollutant transport as a cascade of sheet flows from consecutive terraces along the flow path. The model includes overland, tributary and reservoir routing techniques, as well as surcharging (excess runoff beyond the capacity of the main channel or drain pipe) and observed hydrograph input.

The quality algorithm calculates the buildup and washoff of sediments from the land surface. Various sediment sizes are simulated, with expected percentages of pollutants associated with the sediment sizes (a high percentage of these are associated with smaller sediment sizes). The model simulates toxicants, nutrients and sediments.

PSRM and PSRM-QUAL is an easy to use, menu-driven program written in QUICK-BASIC. Data entered by the user is written to a file and may be edited. Help screens are available to the user.

Once an input file is created, the run option executes the program. Output may be displayed on the monitor or printed out in summary form. Sensitivity runs can easily be performed by modifying input parameters through the use of a multiplier. Output from PSRM-QUAL may be plotted for both the quantity and quality routines.

ILLUDAS - The Illinois Urban Drainage Area Simulator

ILLUDAS stands for Illinois Urban Drainage Area Simulator. It has an option for sizing storm sewers given the basin runoff characteristics, design rainstorm and layout of the sewer network. If the sewer sizes are already known, such as in an existing system, the program will calculate the flows within the entire sewer network. This model was first developed during the 1960s at the Road Research Laboratory in England and was referred to as the RRL method. It was further developed and enhanced by the Illinois State Water Survey and, since it was in public domain, it was made available by the state of IlIinois to anyone upon request. In recent years, this model was converted to a PC version by two individuals working for the Illinois Water Survey and is being distributed as a proprietary model outside of Illinois.

ILLUDAS includes routines for estimating detention storage volumes. One of these routines is a simplification of the flood routing process occurring at a stormwater detention facility. This simplified routing option in ILLUDAS should only be considered for preliminary pre sizing of volumes before serious and more detailed studies are initiated. We refer to this preliminary routing procedure whenever ILLUDAS is discussed. For more information on the model and its capabilities, contact the Illinois State Water Survey.

Detention design using ILLUDAS is performed using certain simplifying assumptions. Of these, the most significant is that the outflow from the detention facility is held constant during the entire detention process, namely, during filling and emptying. This simplification limits the use of ILLUDAS to preliminary systems planning. Figure A-6 illustrates a hypothetical installation that approximates the detention model used by ILLUDAS.

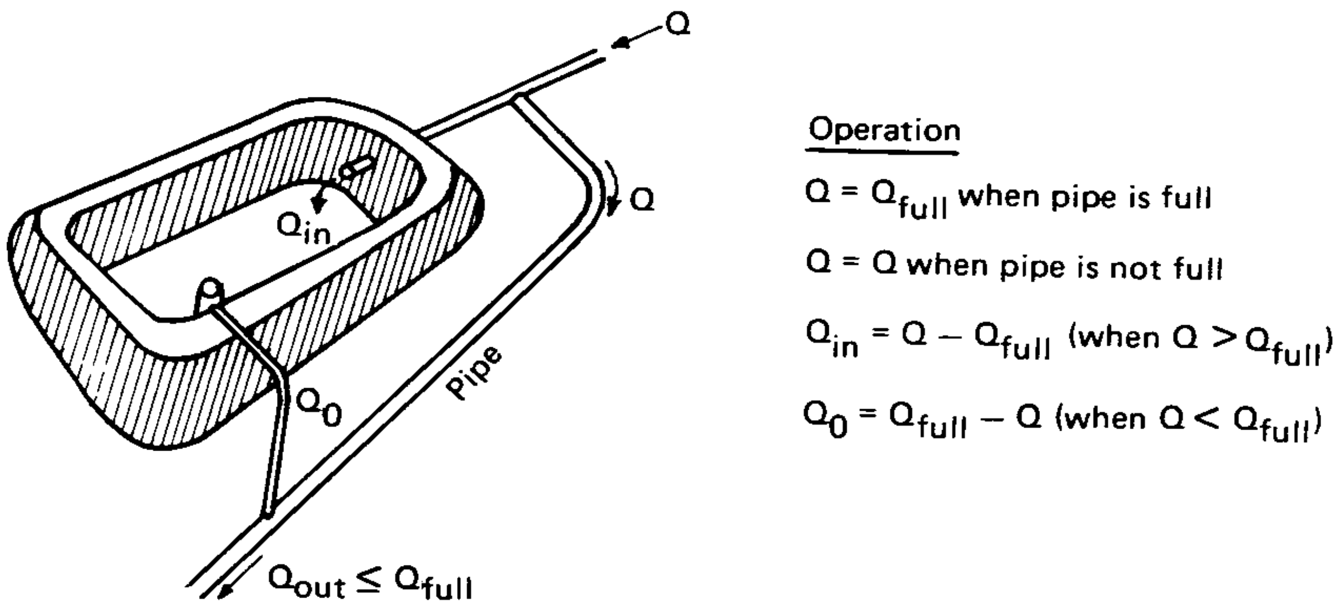

Figure A-6 Example of hypothetical detention as modeled by ILLUDAS (After Terstriep and Stall, 1974)

UDFCD - The Urban Drainage and Flood Control District Model

The Denver Urban Drainage and Flood Control District has developed a model for the computation of runoff hydrographs from urban areas that is known as the Colorado Urban Hydrograph procedure (CUHP).

The Runoff Block of SWMM was substantially modified by the Missouri Division of the Army Corps of Engineers (MRD). This version was further modified to run on a PC for the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado by the Boyle Engineering Company. In rewriting it for the UDFCD, the surface runoff calculations from tributary subbasins were decoupled from the gutter, pipe, detention and other flow routing calculations. As a result, the user needs to generate the subbasin runoff hydrographs only once and then use them as input in subsequent runs. Various flow routing options can thus be studied at considerable savings in computer run time. Description of both models and the software can be obtained free of charge from the Urban Drainage and Flood Control District Denver, Colorado on their web site at www.udfcd.org.

The user may also choose to generate storm runoff hydrographs using the UDFCD's Colorado Urban Hydrograph Procedure (CUHP) program. The output hydrographs from the CUHP program are then read by UDSWM, which routes these hydrographs through the conveyance system, detention facilities, diversions, etc. This program has many of the routing options normally found in the Transport Block of SWMM. It also has some features not found in the Transport Block. Like the MRD Version of the Runoff Block, UDSWM provides the following flow routing elements:

- trapezoidal channels
- circular pipes
- direct flow links (i.e., no flow routing)
- trapezoidal channels with an overflow channel
- circular pipes with an overflow channel
- detention facilities (based on Storage vs. Outflow rating table)

- diversion facilities (based on Flow in Main Flow Element vs. Diverted Flow rating table) and
- out-of-basin inflow hydrographs (based on Time vs. Flow table).

Also, like the MRD version of the Runoff Block, UDSWM offers a single program block with many of the options frequently used in urban stormwater hydrology. In its current version, it has no capability to estimate the runoff and transport of urban runoff pollutants. If storm runoff water quality needs to be modeled, the EPA version of SWMM, despite its shortcomings in simulating pollutant loads, is the model of choice at this time. A feature was recently added to the new version of UDSWM that can automatically design the size of circular storm sewers.

Detention calculations can be performed in two ways using UDSWM. The first option is an informal one and is similar to the methodology in the ILLUDAS model. The user can obtain preliminary detention volume requirements by merely specifying a circular pipe of known flow capacity. The model will route the flows through the pipe until its pipe-full capacity is reached. Any excess flow is then held back in storage until the flows decrease and capacity in the pipe again becomes available to carry off the stored excess. The volume held back this way is reported along with the flow hydrograph and as the maximum volume stored in a summary table. Backwater effects and surcharge in the pipes are not considered in the calculations. As with ILLUDAS, the informal option produces estimated volumes that tend to be on the low side.

The second and formal detention option of UDSWM permits the user to define the outflow vs. storage characteristics for up to 25 detention facilities. The outflow vs. storage input data are used by the program only after the outlet pipe capacity is exceeded. In other words, the program will satisfy the normal depth capacity of the pipe element first before utilizing the outflow vs. storage tables provided by the user. This option permits an experienced user considerable flexibility in testing storage scenarios.

To simulate a surcharged outlet, the user enters the Storage-Outflow table and the characteristics for a very small pipe element that has virtually no flow capacity to satisfy. To approximate an off-line detention facility, the user specifies the pipe size equal to the bypass pipe and then enters the volume outflow table for the flows that exceed its pipe full capacity. UDSWM2- PC is a single event model and will handle one storm event a time. Continuous modeling is not a currently available option.

The formal detention option calculates the storage in the basin using a Modified Pulse flood routing procedure. The time increment used is the user specified time increment of integration for all flow routing calculations in the model. The output consists of a printout that lists all the storage and discharge values throughout the run and the maximum discharge rate and volume stored throughout the storm. Full hydrograph values are printed only for the user specified flow routing elements. A summary table of peak discharge rates and volumes stored, along with their respective times of occurrence, are printed for all routing elements within the model.

UDSWM is a modified version of the SWMM Runoff Block that will run on a PC. The modifications allow the user a variety of flow routing options, including detention facilities. Detention calculations can either be performed informally in a manner similar to how ILLUDAS handles them or formally using the Modified Pulse flood routing procedure. In the latter case, the user can specify up to 500 separate detention facilities anywhere in the flow routing network.

The Santa Barbara Urban Runoff Hydrograph

The Santa Barbara Urban Hydrograph (SBUH) method was developed by the Santa Barbara County Flood Control and Water Conservation District to determine a runoff hydrograph for an urbanized area. It is a simpler method than some other approaches, as it computes a hydrograph directly without going through intermediate steps (i.e., a unit hydrograph) to determine the runoff hydrograph.

The SBUH method is a popular method for calculating runoff, since it can be done with a spreadsheet or by hand relatively easily.The SBUH method depends on several variables:

- Pervious and impervious land areas
- Time of concentration calculations
- Runoff curve numbers applicable to the site
- Design storm,

Other Models

SLAMM - Source Loading and Management Model

The SLAMM model (Pitt and Voorhees, 1989) was originally developed as a planning tool to model runoff water quality changes resulting from urban runoff pollutants. The model has been expanded to include simulation of common water quality BMPs such as infiltration, wet detention ponds, porous pavement, street cleaning, catchbasin cleaning and grass swales.

Unlike other water quality models, SLAMM focuses on small storm hydrology and pollutant washoff, which is a large contributor to urban stream water quality problems. SLAMM computations are based on field observations, as opposed to theoretical processes. SLAMM can be used in conjunction with more commonly used hydrologic models to predict pollutant sources and flows.

P8 - Urban Catchment Model Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds

This model was prepared for IEP, Inc. & Narragansett Bay Project EPA/RIDEM by William W. Walker, Jr. in 1990 and there have been several versions since, the latest being 2.4 in February, 2000.

P8 is a model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of the following elements:

- Watersheds (nonpoint source areas, up to 192 in Version 2.4)
- Devices (runoff storage/treatment areas or BMP's, up to 48 in Version 2.4)
- Particle Classes (up to 5)
- Water Quality Components (up to 10).

Simulations are driven by continuous hourly rainfall and daily air temperature time series. The model was developed for use by engineers and planners in designing and evaluating runoff treatment schemes for existing or proposed urban developments. The model is initially calibrated to predict runoff quality typical of that measured under the EPA's NURP for Rhode Island rainfall patterns. Predicted water quality components include SS (five size fractions), total phosphorus, total Kjeldahl nitrogen, copper, lead, zinc and total hydrocarbons.

Primary applications include site BMP design to achieve SS removal efficiencies (70% or 85%) recommended by the Rhode Island Department of Environmental Management. Simulated BMP types include detention ponds (wet, dry, extended), infiltration basins, swales and buffer strips. Hydrologic components of the program are calibrated and tested against six years of daily streamflow data from the 15,000-acre Hunt-Potowomut watershed, Rhode Island. The model is used to examine the water quality implications of alternative treatment objectives.

Inputs are structured in terms that should be familiar to planners and engineers involved in hydrologic evaluation. Several tabular and graphic output formats are provided. The computer program runs on IBM-PC compatible microcomputers. A companion report (P8 Urban Catchment Model - User's Manual, IEP Inc., 1990) provides an overview and several example applications. Information obtained from: http://www.wwwalker.net/p8/index.html.